would be 0.15 standard liters per minute and the inlet flowrate of steam would be calculated to be 0.45 liters per minute at standard temperature and pressure. For this example, the inlet molar flowrate of methane would be roughly 0.00045 moles per second. These numbers scale linearly with the total reaction chamber volume. A 2 cubic centimeter reaction chamber volume would require 0.0009 moles per second.

Methane conversion is determined by measuring the outlet product composition and the outlet flowrate of methane reforming reaction products and then calculating based on the following formula.

Conversion %=100×(moles methane in−moles methane out)/(moles methane in)

Moles methane in=inlet flowrate of methane at STP/(22.4 L/mol)

Moles methane out=[outlet flowrate of total product dry gas/(22.4 L/mol)]×% methane in dry gas GC analysis

Dry gas is defined as the product gas stream flowrate after condensing the unreacted water or other condensable fluids.

Selectivity to CO %=100×(moles of CO/(moles of CO2+moles of CO+moles of C(s) if present))

Selectivity to CO2%=100×(moles of CO2/(moles of CO2+moles of CO+moles of C(s) if present))

Heat load=(Conversion %/100)×Moles methane in×(Heat of reaction of steam reforming to carbon monoxide at 850 C (226800 J/mol)×selectivity to CO %+Heat of reaction of steam reforming of methane to carbon dioxide at 850 (193200 J/mol)×selectivity to CO2%)/100, units of Watts

Heat flux=Heat load/reactor core volume, units of Watts/cm3

Where the reactor core volume includes all reaction chambers or channels, all associate combustion chambers or channels, and all separating metal webs through which heat transfers between fluids. In short, this volume includes the total volume through which heat transfers for the methane steam reforming reaction. This volume does not include perimeter metal, manifold volume, or other associated packaging that is dependent on individual device geometries.

The following conditions must be met for the combustion reaction that supplies heat for the heat flux measurement test:

1. The gas phase fuel that must be used is hydrogen.
2. The total air flow rate is sized such that a mixture of the hydrogen and air flow rates into the reactor reaches an excess air percentage of 80%. The excess air is defined as the total molar flow rate of oxygen in the combination of hydrogen and air divided by the molar flow rate of oxygen needed to fully oxidize the hydrogen at its molar fuel flow rate. As one mole of oxygen can fully oxidize two moles of hydrogen, 80% excess air corresponds to a 4.28:1 molar ratio of air to hydrogen. Air is taken as 21% mole percent oxygen, balance nitrogen.
3. The hydrogen and air enter the combustion reactor at 900° C.
4. The air and hydrogen are to be mixed either in a manifold that is directly upstream of the combustion reactor or in the reactor itself.
5. The standard volumetric flow rates for hydrogen through the combustion reactor per 0.15 SLPM of methane flow rate through the methane steam reforming reactor is a minimum of 0.140 SLPM and a maximum of 0.204 SLPM.
6. The corresponding minimum and maximum air flow rates through the combustion reactor, based upon the 80% excess air condition, per 0.15 SLPM of methane flow rate through the methane steam reforming reactor is 0.600 SLPM and 0.875 SLPM, respectively.
7. The inlet pressures of the hydrogen and air streams should be no greater than 2.38 bar (20 psig).

Pressure Test—High Temperature test for ICR

In preferred embodiments, any of the devices described herein are capable of withstanding internal pressure differences. For example, some preferred embodiments meet the requirements of the following pressure test. For a microchannel unit operation device with at least one critical channel dimension less than about 2 mm, operate with at least two inlet fluid streams. The first fluid stream must be at 850 C and 180 psig. The second fluid stream must be at 800 C and 10 psig. Any flow rate may be used. Operate the device with gas flow to both streams for 300 hours. After 300 hours operation, pressurize each fluid flow line to 50 psig and hold for 2 hours. The pressure must remain constant indicating minimal leak paths to the environment. Then, pressurize the second fluid flow line to 50 psig, leaving the first fluid flow line open to atmosphere, and hold for 2 hours. The pressure must remain constant indicating minimal internal leak paths. A minimal leak path is defined as a leak rate of less than 10^{-6} standard cubic centimeters per second of helium when helium is used as the fluid for the final leak test.

The invention also includes methods of conducting unit operations in the device having the pressure resistance characteristic described above.

We claim:

1. An integrated reactor, comprising: a first reaction chamber having a height, width-and length, wherein there is an open path through the first reaction chamber, wherein the first reaction chamber has an internal volume comprising 5 to 95 vol. % of porous catalyst and 5 to 95 vol. % of open space; and a second reaction chamber having a height, width-and length, wherein there is an open path through the second reaction chamber, wherein the second reaction chamber has an internal volume comprising a catalyst and at least 5 vol. % of open space; and a reaction chamber wall separating the first chamber and the second chamber; and wherein the integrated reactor possesses a NOx output characteristic of less than 100 ppm as measured according to the Standard NOx Test Measurement; and wherein the first reaction chamber comprises a bulk flow region comprising a cross-sectional area in the range of 5×10^{-7} to 1×10^{-4} m^2.

2. The integrated reactor of claim **1** wherein the first reaction chamber has a width of 2 mm or less; and wherein the integrated reactor possesses a heat flux characteristic of 1 W/cc to 120 W/cc as measured according to the Heat Flux Measurement Test.

3. The integrated reactor of claim **1** comprising at least 5 layers of endothermic reaction chambers alternating with at least 4 layers of exothermic reaction chambers.

4. The integrated reactor of claim **1** wherein the porous catalyst comprises a pore volume and wherein at least 50% of the pore volume is composed of pores in the size range of 0.1 to 300 micrometers.

5. The integrated reactor of claim **1** wherein the porous catalyst comprises a pore volume and wherein at least 20% of the pore volume is composed of pores in the size range of 0.3 to 200 micrometers.

6. An integrated reactor, comprising: a first reaction chamber having a height, width and length, wherein there is an open path through the first reaction chamber, wherein the first reaction chamber has an internal volume comprising 5 to 95